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# ART. VIII.—*An Example of Gravitational Drift of Rock Debris in Parallel Lines in Sub-Arid Western Australia.*

BY J. T. JUTSON.

(With Plate V., Figure 3.)

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## Gravitational Drift of Rock Debris in General.

One of the most striking features of portions of the interior of sub-arid Western Australia is the widespread surface covering of fragments of the hardest rocks. These fragments may rest on bedrock, or, as in most cases, on the surface soils; and the action of rain and wind removes any fine material that lodges on or between such rock fragments, so that the stony character of the ground is maintained over wide areas. These rocky fragments are usually not more than three or four inches in size, and are frequently less than this. They form in places the "pebble armour of the desert," as described for other areas, by Hobbs[1] and by Mawson[2]. Such areas are also termed "stone fields."

This rock debris must often have travelled considerable distances, but the rocks that do so are only the hardest, such as quartz, dense ironstones and jaspers. Fragments of most other rocks, even those usually regarded as hard and weather-resisting, such as some fine-grained basic ones, are practically never found far from the parent rocks, showing that their disintegration must be comparatively rapid. This fact is of value in geological mapping.

As to the mode of travelling of the hard fragments, the direct transporting action of water seems, except along the beds of some watercourses, to be out of the question. The travelling rock debris, however, is not restricted to these watercourse beds, but is found in all positions, and, amongst others, on gentle slopes where nothing but gentle rills of water, without any de-

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1. Hobbs, W. H.—"The Erosional and Degradational Processes of Deserts, with Especial Reference to the Origin of Desert Depressions." Annals Assoc. Am. Geog., Vol. VII., p. 48.

2. Mawson, D.—"Geological Investigations in the Broken Hill Area." Mem. Roy. Soc., South Aust., Vol. II., 1912, p. 230.

fined channels, at times flow, and these are quite unable to move the rock debris[3].

Such debris seems to travel slowly along by mere gravitational drift, aided or brought about by the removal of the underlying soil by rain and wind, on account of which the fragments topple forward. The "clawing" action of rain, which the writer has already described[4], is a potent factor in this respect.

As a general rule there is no particular arrangement of the rock debris except in the case of the remarkable mosaics, or "desert pavements," and in the example to be now described of the drift of the rock debris in parallel lines.

## Gravitational Drift of Rock Debris in Parallel Lines.

The example of this parallel drift occurs on the floor of Lake Goongarrie, a "dry" lake immediately to the east of the mining township of Goongarrie, which is 55 miles north of Kalgoorlie. The bed rock is a compact, almost black, shale, somewhat indurated, which breaks easily under the hammer in hand specimens, but which, when it forms a floor, as it does here, is quite firm. The shale is well laminated and strikes about N. $10^0$ W.; it is practically vertical, but dips if anything to the west. At the precise locality referred to, it is quite free from debris, except for the quartz detritus to be presently described. In the shale is a quartz reef, with approximately the same strike and dip as the shale itself. This reef is a foot or more thick, and some yards in length. It projects from two to four feet above the shale. The reef is breaking down into fragments of various size, and these fragments drift over the shale away from the reef. This drifting material protects, to some extent, the shale from erosion, so that the ground rises into a low hillock, culminating in the quartz reef, a few feet above the surrounding ground. It is on the eastern side of this reef that the example referred to occurs, and the greatest inclination (which however, is only a few degrees) of the ground on this side of the reef is to the east, and at right angles to the strike of the shales. Water falling on the hillock on the eastern side of the reef therefore flows *across* and *not with* the strike of the shales.

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3. See Jutson, J. T.—"Sheet-flows, or Sheet-floods, and their associated phenomena in the Niagara District of sub-arid south-central Western Australia." Am. Journ. Science, Vol. XLVIII (1919), pp. 435-439.
4. Proc. Roy. Soc. Vict., Vol. XXXII. (N.S.), Part I. (1919), pp. 20-21.

On this eastern side of the hillock, the white quartz debris (which is in fragments of all sizes up to six or more inches in length) is arranged in parallel lines, which are in turn parallel to the strike of the rocks, with spaces between the various lines, free or largely free, from the quartz debris. These interspaces, therefore, are the colour of the underlying shales, which here are almost black. There are thus more or less alternate dark-coloured and white bands parallel to one another and to the strike of the rocks, represented by the shales and by the quartz debris respectively. The width of the bands varies from about three to six inches. The dark-coloured areas are not entirely free from quartz, nor are the quartz bands quite continuous, but distinct parallel bands do exist as described above.

As regards the mode of formation of these parallel bands, the direct action of rain must be excluded. No fall would be sufficient to remove the larger fragments of quartz. Moreover the inclination of the ground, and consequently the flow of water when rain falls, are across and not with the parallel bands, and hence the rain could not form the furrows described below. It may also be noted that immediately after rain, the banding is much less distinct, in consequence of fine sand being washed out from the quartz bands on to the shale bands. The only possible explanation of the banding that occurs to the writer is that the wind is mainly responsible. Fine sand is available from the quartz decay, and from adjacent areas. The shales are eroded differentially by ordinary disintegration and weathering along their line of strike in their exposed parts, that is, where the quartz rubble is scarcest. The wind sweeps this disintegrated portion away as well as probably rasping the surface with the fine sand available. This tends to create a furrow running at right angles to the slope of the ground. In addition, the quartz rubble becomes undermined by removal of the underlying shales by the same action, with the result that the quartz fragments topple forward—no doubt gradually—and fall into the furrow. The " ridge " lately occupied by the quartz debris then similarly becomes furrowed, and the band of quartz debris behind, then occupies such furrow. Thus there is a slow gravitative drift of the quartz debris in parallel lines, and at the same time the shale surface is gradually being lowered as a whole. The furrows formed in this way are somewhat akin to the " yardangs " of arid North America and elsewhere.

The suggested explanation has objections to it. A number of loose stones of various sizes and shapes would apparently move forward, even under the special conditions of furrowing postulated, at very different times, and thus the parallelism of the lines would be destroyed; and before it was regained, practically the whole of the stones on the "ridge" would have to fall into the furrow. This could possibly, and perhaps does, as suggested above, occur, since the stones remaining on the ridge would continue to be undermined, whilst those reaching the furrow would escape this process for the time being. Such a peculiar combination of conditions may occasionally result, but it could hardly be expected to be widespread, and apparently it is not. The matter is brought forward so that further instances in Western Australia or elsewhere might be searched for and studied in the field. So far as the writer is aware, no other example of gravitational drift of rock debris in parallel lines has been recorded.

Tolman[5] has emphasized the importance of a "desert pavement" as a protection of the underlying rocks against erosion. Such pavements of quartz occur at Goongarrie, and will be described in another paper. The present paper, however, shows that where the pavement is not complete, although there is a measure of protection, yet considerable erosion may take place. It may be remarked in this connection that S. Göczel[6] had as early as 1894 pointed out that the pebble-covered areas were a protection against wind erosion of the underlying material.

## DESCRIPTION OF PLATE V., Figure 3.

Fig. 3.—The white quartz debris is derived from the reef in the background. Bands of black shales are shown alternating with parallel bands of quartz debris, especially in the foreground. The bands are parallel to the strike of the shales.

Floor of Lake Goongarrie.

5. Tolman C. F.—"Erosion and Deposition in the Southern Arizona Bolson Region." Journ. Geol., 1909, Vol. XVII., p. 149.

6. Göczel, S.—"Report on the Central Goldfields of Western Australia," Appendix V., pp. 24-33. Ad Interim Report of the Department of Mines for half-year ending 30th June, 1894.